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Amino acid levels and energy specifications in SBM for poultry and pigs

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Introduction

Soybean meal (SBM) is the most widely used ingredient source of amino acids for pig and poultry diets in the world. Accurate formulation requires reliable amino acid and energy values for all ingredients. For SBM, this is more easily achieved for amino acids than for energy. Analytical options for amino acids have evolved to include better procedures (especially tryptophan). This includes near-infrared spectroscopy (NIRS) which uses larger sample sizes to improve estimation. Net energy (NE) values for growing pigs, on the other hand, are computed from compositional components and resulting estimates vary considerably among international references. We are unclear about the accuracy of metabolizable energy (ME) estimates for growing poultry, however, these are easier to prove or disprove.

We published amino acid and energy values for SBM over the 44.0 to 48.0% crude protein (CP) range and applied those values in serial formulations to evaluate the economic value of increasing the amino acid content of SBM (Pope et al., 2023). Amino acid composition and respective prediction equations, ME for growing poultry and NE estimates for growing pigs were presented and are reported here to increase access to them. SBM ME values for poultry were derived from Rostagno et al. (2017). The SBM NE values that we presented for growing pigs are in agreement with growth assays in the private sector and recent calorimetry studies by the University of Illinois. The latter technology is the basis for our assertion that prediction equations used by international references underestimate SBM NE value for pigs (Lee et al., 2022).

Equations for predicting total amino acid content from SBM CP are provided to benefit all end-users. SBM ME for growing poultry and NE estimates for growing pigs are considered to be minimum values. Although the NE values align with recent pig growth assay and calorimetry results under experimental conditions, we assert that they are minimum because recent estimates that were obtained under commercial conditions appear to be higher than those determined in academic environments (Cemin et al., 2020). We discuss the conceptual basis for the prospect of achieving different answers in the two settings below.

Prediction of amino acid content in SBM

We determined amino acid levels for the range of SBM CP classes that are typically encountered in practice and developed equation parameters to enable dynamic prediction for each amino acid based on CP level (**Table 1**; Pope et al., 2023). This information was obtained by NIRS analysis of SBM samples collected over a 9 month period and that ranged from 43.7 to 48.6% CP. A total of 169 truckload samples of SBM were obtained upon delivery to a feed manufacture plant (Hanor Co., Greenfield IL). The SBM samples were sourced from 2 Illinois soybean processing facilities. Dry matter (DM) and CP content were determined by NIRS. NIRS spectra for the 10 essential amino acids were taken at the feed plant but the amount of each amino acid was determined by Evonik (collaborating supplier) using their proprietary technology. Descriptive statistics for the amino acid data set are provided in **Table 2** so that variation and distribution for each amino acid in the sample set is transparent.

Among the advantages of a properly calibrated NIRS, as compared to wet chemistry, is that the sample size analyzed is comparatively large; therefore, inherent human error in analysis is reduced. We further controlled variation in amino acid estimates by expressing the results for each SBM sample on a constant DM basis (88.0%). These and other steps were important to reducing variation in results. We observed a strong linear relationship between CP level and content for

Table 1. Total amino acid content (%) and linear equation parameters for SBM protein classes equated to 88.0% DM basis[1,2]

Item	Met	Cys	Met + Cys	Lys	Thr	Trp	Isoleu	Val	His	Arg	Leucine
Intercept	0.0410	-0.1064	0.0051	-0.1681	0.0298	0.0075	-0.2361	-0.1168	-0.0524	-0.6290	-0.1321
Slope	0.0131	0.0175	0.0286	0.0662	0.0384	0.0137	0.0507	0.0501	0.0275	0.0869	0.0784
P-value	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
R-Square	0.7902	0.5276	0.6801	0.8809	0.9066	0.8577	0.9024	0.9596	0.8868	0.9382	0.9207
Cr Protein, %											
44.0	0.6192	0.6651	1.2641	2.7453	1.7182	0.6122	1.9938	2.0887	1.1585	3.1934	3.3158
45.0	0.6324	0.6826	1.2927	2.8115	1.7566	0.6259	2.0445	2.1389	1.1860	3.2803	3.3942
46.0	0.6455	0.7001	1.3213	2.8777	1.7950	0.6397	2.0952	2.1890	1.2135	3.3672	3.4725
47.0	0.6586	0.7177	1.3500	2.9440	1.8333	0.6534	2.1459	2.2391	1.2411	3.4541	3.5509
48.0	0.6718	0.7352	1.3786	3.0102	1.8717	0.6671	2.1966	2.2892	1.2686	3.5409	3.6293

[1] Adapted from tabular information in Pope et al., 2023.

[2] Slope and intercept parameters apply to linear equation predicting total amino acid level (%) from SBM CP level (%), $P<0.0001$.

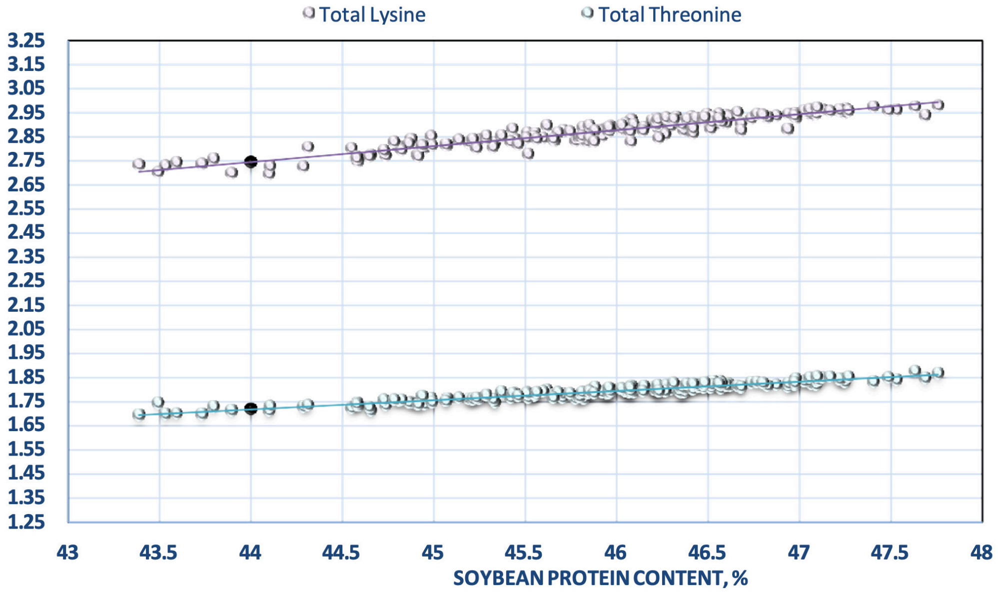
Table 2. Descriptive statistics for dry matter (DM), protein (CP) and total amino acid content for SBM samples equated to 88.0% DM[1]

Item	DM	CP	Met	Cys	Lys	Thr	Trp	Ile	Val	Arg	His	Leu
Median, %	88.58	46.27	0.651	0.707	2.896	1.808	0.644	2.110	2.203	3.391	1.221	3.501
Mean, %	88.58	46.23	0.649	0.703	2.892	1.804	0.643	2.105	2.200	3.383	1.219	3.489
Maximum, %	91.52	48.62	0.680	0.743	3.035	1.915	0.673	2.231	2.322	3.579	1.290	3.704
Minimum, %	87.11	43.67	0.607	0.636	2.678	1.697	0.599	1.950	2.066	3.150	1.139	3.264
SD [2]	0.63	0.96	0.014	0.022	0.067	0.041	0.014	0.052	0.050	0.083	0.028	0.081

[1] Approximately 1 kg sample collected from 21.78 MT truck Lots by serial sampling at unloading. Total of 36,808 MT SBM delivered to Feed manufacture plant over 9 month period with 169 samples collected. SBM source plants (IL): 53 truck Lots from Solae Co. and 116 from ADM.

[2] SD, Standard deviation

Figure 1. Plot of total lysine and threonine content (%) regressed on protein content of respective SBM samples (%), expressed on 88.0% DM basis.



each amino acid. This is illustrated for lysine (Lys), threonine (Thr) and tryptophan (Trp) in **Figures 1 – 2** (SD in **Table 2**).

These prediction equations allow nutritionists to estimate the total content for each amino acid over the CP range normally encountered (**Table 1**), if they do not already have access to equation parameters from a trusted source. Estimates for Trp are of particular interest since it has been difficult to obtain reliable chemical estimates in the past because extensive Trp hydrolysis can occur during protein hydrolysis. NIRS estimates for Trp involved calibrations to chemical estimates using improved hydrolysis procedures (Fontaine, 2003).

Prediction equations are perhaps most applicable if they are developed by region because soybean sources in different regions may involve a different mix of genetics and environment for growth. Genetic variation alone can slightly alter the amino acid composition if varieties differ in the proportion of glycinin and (or) β-conglycinin in the protein. These two classes account for 65-80% of soybean protein classes (Wang and de Mejia, 2005). Ultimately, the value of region-specific equations can only be realized if NIRS or wet chemistry analysis is competent. Laboratory options for analysis must be proven accurate and repeatable. More accurate estimates of amino acids from SBM CP content, within a region and throughout the year, require a properly calibrated NIRS (expert external collaboration may be needed) with periodic adjustment of prediction parameters.

Information presented (**Table 1**) is easily converted to the standardized ileal digestible (SID) format for formulation using ingredient coefficients that are available from various sources, as reported by Pope and co-workers (2023). Ultimately, the preferred approach for nutrition end-users will evolve to the use of real-time SID amino acid values from each processing plant (Boyd et al., 2019), since processing conditions vary in ways that affect amino acid availability to the animal. NIRS determination of reactive lysine is increasingly used to predict digestible lysine content for processed foods and feeds. It is a robust and reliable means of detecting changes in lysine availability of SBM that arise from process variations (Kim and Mullan, 2012).

Figure 2. Plot of total tryptophan content (%) regressed on protein content of respective SBM samples (%), expressed on 88.0% DM basis.

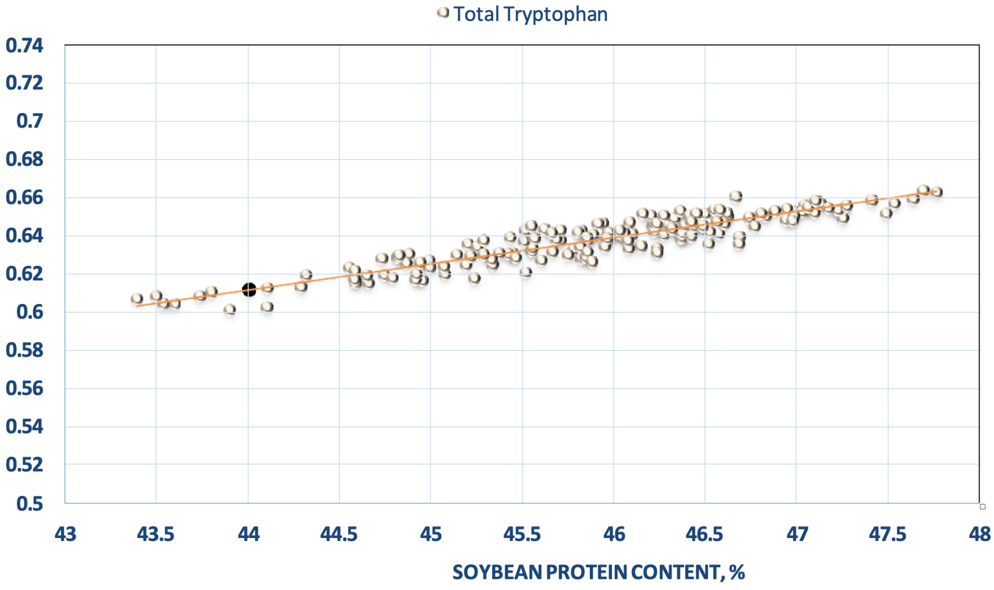


Table 3. Percentage of the most limiting essential amino acids for each SBM CP level are relatively constant over the SBM CP range (44.0 to 48.0%)[1,2]

	Select Amino Acids : Protein %			SUM
SBM CP	Met + Cys	Top 4	Top 6	Top 6
44.0	2.87	14.41	23.69	10.42
45.0	2.87	14.42	23.71	10.67
46.0	2.87	14.42	23.73	10.92
47.0	2.87	14.43	23.76	11.17
48.0	2.87	14.43	23.78	11.41

[1] Percentage for each amino acid class calculated for example: Total Met + Cys in 44.0% CP / 44.0% CP x 100

[2] Top 4 limiting amino acids: Lys, Thr, Met + Cys, Trp; Top 6 limiting amino acids: Top 4 amino acids + Ile, Val.

Limiting amino acid ratio change with SBM CP level?

The question of whether the most limiting essential amino acids vary in proportion to SBM CP over the range encountered in practice is often raised. For example, is it possible for a lower CP SBM source (e.g., 45.5 vs 47.5%) to have greater dietary value than expected because its' ratio of the most limiting amino acids to CP is elevated compared to a higher SBM CP source? If this were true, the financial penalty for a lower CP source would be partially offset. This does not appear to be the case based on this data set (**Table 3**) since the proportion of the most limiting amino acids (growing pigs, poultry) to CP content did not change for any of the following categories:

(1) Met+Cys,

(2) Lys, Thr, Trp, Met+Cys (Top 4 limiting amino acids)

(3) Top 4 + Ile, Val (Top 6 limiting amino acids)

The proportion of SBM CP that is represented by the most limiting amino acids noted above was remarkably constant over the CP range we studied.

Minimum ME and NE specifications for SBM

It is difficult to obtain estimates for SBM energy (ME, NE) that cover the CP classes encountered in practice. Among the international references on ingredient values, the Brazilian Feed Composition tables (Rostagno et al., 2017) provide tabular estimates for more SBM CP classes than does the NRC (2012, National Research Council), INRA (2004, French National Institute Agricultural Research) or CVB (2016, Centraal Veevoederbureau). They addressed the need for dynamic prediction of ME or NE in relation to SBM CP level was by publishing algorithms. However, they underestimate SBM NE for growing pigs based on recent calorimetry (Lee et al., 2022) and growth assay research (Boyd and Rush, 2018).

Consequently, we suggested minimum SBM energy values for growing poultry and pigs (Pope et al., 2023; **Table 4**). Poultry ME values were derived from Brazilian Feed Composition tables (Rostagno et al., 2017), equalized for DM and oil content, and then regressed on SBM CP level to derive the best ME estimate for each SBM CP class. We derived SBM NE estimates for growing pigs using recent calorimetry (Lee et al., 2022) and growth validation assays (Boyd and Rush, 2018) as the starting point. These values proved to be remarkably similar. NE estimates were expanded over the full range of SBM CP (44.0 to 48.0%) by deviating NE in relation to SBM CP based on incremental NE changes computed from Brazilian and CVB references.

We compared the resulting estimates of SBM NE in relation to SBM CP level **(Table 4)** to values derived from an ingredient energy prediction model that is used by a leading private nutrition firm (similar composition). We found them to be consistent with the values in **Table 4**. This firm was chosen because their model has been calibrated by pig growth assay (feed conversion efficiency, FCE). These energy values (**Table 4**) were regressed on respective SBM CP levels so that energy relationships could be leveraged over a continuum of CP levels between 44.0 and 48.0% (**see Table 4 footnote**).

SBM energy appears to increase with increasing CP

It is noteworthy that the two referenced sources (Rostagno et al., 2017; CVB, 2016) and the private nutrition firm model each show an increase in energy value as SBM CP increases (data not shown). The rate of increase in ME and NE in relation to SBM CP increase (from 44.0 to 48.0%) is illustrated in **Figure 3**. With 48.0% CP SBM defined as the reference point, we computed that 44.0% CP SBM (at equivalent DM and oil content) would contain about 4.0% less NE for pigs and 5.8% less ME for poultry. This index of relative energy content would be expected, if an increase in protein displaces complex carbohydrates which have less digestible energy. The accuracy of this positive association between SBM CP and energy needs to be verified using animal calorimetry.

Table 4. Suggested SBM energy values for growing Poultry and Pigs on 88.0% DM

	SBM Crude Protein Class, %				
Item	**44.0**	**45.0**	**46.0**	**47.0**	**48.0**
Poultry[2, 4]					
ME, Mcal/kg	2.120	2.153	2.185	2.217	2.250
Pigs[3, 4]					
NE, Mcal/kg	2.113	2.148	2.177	2.188	2.200

[1] SBM energy values adapted from Pope et al., (2023) by expressing them on an 88.0% DM basis.

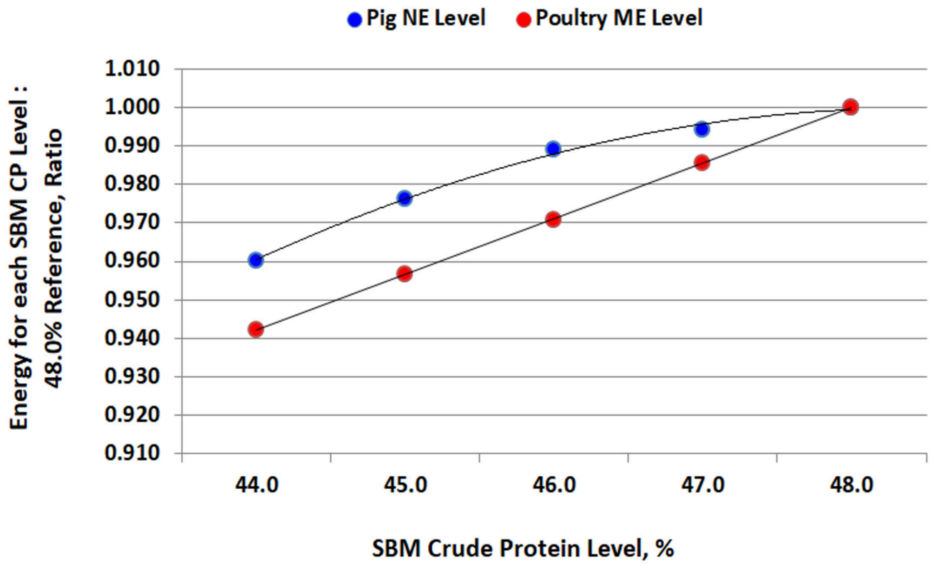
[2] SBM ME values (4) for Poultry obtained from Feed composition tables (Rostagno et al., 2017), standardized for DM (88.7%) and Oil (1.80%) and regressed on SBM CP level so SBM NE can be calculated over a CP continuum. Resulting equation: SBM ME, kcal/kg = 32.856 x CP + 691.05; Linear, $P = 0.089$ with $R^2 = 0.8293$.

[3] SBM NE values for growing pigs were predicted, as stated in the text, standardized for DM, Oil content then regressed on SBM CP level for NE prediction over the continuum of SBM CP encountered. Equation: SBM NE, kcal/kg = $-4.4286 \times CP^2 + 429.03 \times CP - 8173.2$; Quadratic, $P = 0.129$, $R^2 = 0.9858$

[4] Estimate is then equated to the actual DM if it differs from 88.0%

Figure 3. SBM energy values increase as SBM CP increases.

Calculations are based on ME and NE values found in Table 4 expressed as a ratio to 48.0% CP; the latter being the reference point and defined as 1.000.



In practice, there is greater dietary value for SBM as CP increases, but the magnitude increases more if amino acid level and energy (NE, ME) both increase. Based on the relationships shown in **Table 4**, Pope and co-workers (2023) reported that each 1.0% increase in SBM CP (from 44.0 to 48.0%) increased feed value by approximately $10.27 and $12.62 per metric ton for swine and poultry, respectively. This relationship may vary in magnitude as prices fluctuate, however, the principle is resilient over a wide range of ingredient price relationships. This is important knowledge for all participants in the SBM supply chain (plant geneticists, growers, processors and end-users).

SBM NE may be greater in commercial environment

In practice, some swine nutritionists in the U.S. value SBM NE above the estimates in Table 4. Values in the order of 90-110% of standard corn NE (NRC 2012) have been disclosed. We presented the SBM NE estimates as minimum values because they are grounded in animal growth and calorimetry assays that were conducted in academic settings or similar controlled environments that lack pathogen stress encountered in commercial barns housing 1000 or more pigs per room. The recent study by Cemin and co-workers (2020), conducted in collaboration with JBS Pork systems, lends credence to higher SBM NE value being expressed in the commercial environment. They reported that SBM NE relative to the corn standard was > 105% of corn under field test conditions. This suggests a non-nutritive increase in expressed NE. The basis for a non-nutritive effect of SBM on realized NE when animals are under significant pathogen stress was suggested by Boyd and co-workers (2010). In their study, diets with higher SBM content attenuated the suppressing effect of respiratory immune stress on FCE and gain. The growth and health-promoting nature of SBM results from the abundant and diverse source of functional molecules that it contains (Wang and de Mejia, 2005; Smith and Dilger, 2018).

The next article will address our proposal that SBM NE in a commercial environment may be relatively greater than substrate-based NE estimates that are the framework for ingredient values. SBM is in a small class of ingredients that have a significant content of functional components that may alter the efficiency of metabolism (reduce heat increment). The net effect would be to improve FCE beyond the energy substrate contribution; FCE being the key measure of energy use in the growth assay. In view of this possibility, productive energy (PE) would be a more appropriate term for SBM since PE encompasses energy derived from (1) energy substrates, and by (2) energy conservation that may arise from improved metabolic and (or) immune efficiency (*non-substrate component*).

The latter is a dimension that probably requires a commercial environment (e.g. pathogen stress) in order to be expressed sufficiently to be measurable. Thus, we introduce the concept that certain ingredients may have natural components 'on-board' that can improve metabolic or immune efficiency when certain stressors are imposed.

Key Conclusions

1) Accurate formulation with SBM requires reliable amino acid and energy value, but NE estimates in international references are underestimates.
2) SBM amino acid and energy (ME, NE) content for poultry and pigs was expressed relative to SBM protein level over the 44.0 to 48% range since both increase as SBM CP increases.
3) SBM value increases in swine and poultry diets as protein increases, but the magnitude is greater if both amino acids and energy increase.
4) SBM NE value appears to be greater under field conditions where health-promoting molecules are more likely to improve metabolic efficiency.

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